Resolving the Degeneracy: Experimental tests of the New Self Creation Cosmology
and a heterodox prediction for Gravity Probe B

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Abstract

The new theory of Self Creation Cosmology has been shown to yield a concordant cosmological solution that does not require inflation, exotic non-baryonic Dark matter or Dark Energy to fit observational constraints. In vacuo there is a conformal equivalence between this theory and canonical General Relativity and as a consequence an experimental degeneracy exists as the two theories predict identical results in the standard tests. However, there are three definitive experiments that are able to resolve this degeneracy and distinguish between the two theories. Here these standard tests and definitive experiments are described. One of the definitive predictions, that of the geodetic precession of a gyroscope, has just been measured on the Gravity Probe B satellite, which is at the present time of writing in the data processing stage. This is the first opportunity to falsify Self Creation Cosmology. The theory predicts a 'frame-dragging' result equal to GR but a geodetic precession of only 2/3 the GR value. When applied to the Gravity Probe B satellite, Self Creation Cosmology predicts an E-W gravitomagnetic/frame-dragging precession, equal to that of GR, of 40.9 milliarcsec/yr but a N-S gyroscope (geodetic + Thomas) precession of just 4.4096 arcsec/yr.

1 Introduction

1.1 The Principles of the Theory

1.1.1 Self Creation Cosmology Theories

This author has described a new Self Creation Cosmology (SCC) (Barber, 2002a) with interesting empirical predictions (Barber, 2002b). This theory superceded two earlier toy theories (SCC1 & SCC2) (Barber, 1982), of which SCC1 was discarded as experimentally and internally inconsistent and SCC2

was subsequently found to be a particular representation of the latest theory. All three SCC theories produce continuous creation by modifications of the scalar-tensor Brans-Dicke theory (BD), (Brans & Dicke, 1961) in which the conservation of energy-momentum is relaxed in order to explore cosmologies in which the matter universe may be created out of self-contained gravitational, scalar and matter fields. They have generated some interest in the literature with approximately 54 citations published over the last 20 years [see (Barber, 2002b)].

In these theories Mach's Principle (MP) is incorporated by assuming the inertial masses of fundamental particles are dependent upon their interaction with a scalar field ϕ coupled to the large scale distribution of matter in motion in a similar fashion as BD. This coupling is described by a field equation of the simplest general covariant form

$$\Box\phi = 4\pi\lambda T_M \ , \tag{1}$$

T_M is the trace, $(T_M{}^\sigma{}_\sigma)$, of the energy momentum tensor describing all non-gravitational and non-scalar field energy.

1.1.2 The New Self Creation Cosmology

In the new theory the BD coupling parameter λ was found to be unity, (Barber, 2002a) and in the spherically symmetric One Body problem

$$\underset{r\to\infty}{Lim}\ \phi\left(r\right) = \frac{1}{G_N} \ , \tag{2}$$

where G_N is the normal gravitational constant measured in Cavendish type experiments.

In both General Relativity (GR) and BD the equation describing the interchange of energy between matter and gravitation is,

$$\nabla_\mu T_M{}^\mu{}_\nu = 0 \ , \tag{3}$$

however in all the SCC theories this condition, which arises from the Equivalence Principle, is relaxed. In the latest SCC theory it was replaced by the Principle of Mutual Interaction (PMI) in which

$$\nabla_\mu T_M{}^\mu{}_\nu = f_\nu\left(\phi\right)\Box\phi = 4\pi f_\nu\left(\phi\right)T_M \ , \tag{4}$$

and therefore *in vacuo,*

$$\nabla_\mu T_{em}{}^{\mu}{}_{\nu} = 4\pi f_\nu(\phi)\, T_{em} = 4\pi f_\nu(\phi)\,(3p_{em} - \rho_{em}) = 0 \tag{5}$$

where p_{em} and ρ_{em} are the pressure and density of an electromagnetic radiation field with an energy momentum tensor $T_{em\,\mu\nu}$ and where $p_{em} = \frac{1}{3}\rho_{em}$. Thus the scalar field is a source for the matter-energy field if and only if the matter-energy field is a source for the scalar field. Although the equivalence principle is violated for particles, it is not for photons, which still travel through empty space on (null) geodesic paths.

The effect of the PMI is that particles do not have invariant rest mass. A second principle, the Local Conservation of Energy, was introduced to determine the variation in rest mass. It requires a particle's rest mass to include gravitational potential energy and is described by

$$m_p(x^\mu) = m_0 \exp[\Phi_N(x^\mu)] \ , \tag{6}$$

where $\Phi_N(x^\mu)$ is the dimensionless Newtonian potential and $m_p(r) \to m_0$ as $r \to \infty$.

There is a conformal equivalence between canonical GR and the SCC Jordan Frame that results in the geodesic orbits of SCC being identical with GR *in vacuo*. Two conformal frames were defined; the Jordan energy frame [JF(E)], which conserves mass-energy, and the Einstein frame (EF), which conserves energy momentum. The two conformal frames are related by a coordinate transformation

$$g_{\mu\nu} \to \widetilde{g}_{\mu\nu} = \Omega^2 g_{\mu\nu} \ . \tag{7}$$

A mass is conformally transformed according to

$$m(x^\mu) = \Omega \widetilde{m}_0 \ , \tag{8}$$

Equation 6 requires

$$\Omega = \exp[\Phi_N(x^\mu)] \ , \tag{9}$$

where $m(x^\mu)$ is the mass of a fundamental particle in the JF and $\widetilde{m}_0$ its invariant mass in the EF. The conformal equivalence with canonical GR is a consequence of the coupling constant

$$\omega = -\frac{3}{2} \ ,$$

and then defining the EF by $G = G_N$ a constant. This value for ω may simply be set empirically, but it can be shown to be required from first principles (Barber, 2003).

1.2 The SCC Field Equations

The result of these three requirements gave the following fundamental, manifestly covariant, field equations:

The scalar field equation

$$\Box\phi = 4\pi T_M \ , \tag{10}$$

the gravitational field equation

$$\begin{aligned} R_{\mu\nu} - \frac{1}{2}g_{\mu\nu}R &= \frac{8\pi}{\phi}T_{M\mu\nu} - \frac{3}{2\phi^2}\left(\nabla_\mu\phi\nabla_\nu\phi - \frac{1}{2}g_{\mu\nu}g^{\alpha\beta}\nabla_\alpha\phi\nabla_\beta\phi\right) \\ &\quad + \frac{1}{\phi}\left(\nabla_\mu\nabla_\nu\phi - g_{\mu\nu}\Box\phi\right) \ , \end{aligned} \tag{11}$$

and the creation equation, which replaces the conservation equation (Equation 3)

$$\nabla_\mu T_{M\ \nu}^{\ \mu} = \frac{1}{8\pi}\frac{1}{\phi}\nabla_\nu\phi\Box\phi \ . \tag{12}$$

1.3 The Static, Spherically Symmetric Solution

The Robertson parameters are

$$\alpha_r = 1 \qquad \beta_r = 1 \qquad \gamma_r = \frac{1}{3} \ , \tag{13}$$

and therefore the standard form of the Schwarzschild metric is

$$\begin{aligned} d\tau^2 &= \left(1 - \frac{3G_N M}{r} + ..\right)dt^2 - \left(1 + \frac{G_N M}{r} + ..\right)dr^2 \\ &\quad - r^2 d\theta^2 - r^2\sin^2\theta d\varphi^2 \ . \end{aligned} \tag{14}$$

The formula for ϕ is

$$\phi = G_N^{-1}\exp(-\Phi_N) \tag{15}$$

and that for m is, (Equation 6),

$$m_p\left(x_\mu\right) = m_0\exp(\Phi_N).$$

The effect of breaking the equivalence principle in accordance with the PMI is that there is an extra scalar field force, which acts on particles but not photons, that behaves as Newtonian gravitation except in the opposite direction. There are therefore two gravitational constants, one felt by photons, G_m , is that describing the curvature of space-time and the other G_N is that felt by particles and is the normal Newtonian gravitational constant measured in Cavendish type experiments.

A detailed calculation yields (Barber, 2002a)

$$G_N = \frac{2}{3} G_m \ , \tag{16}$$

so the acceleration of a massive body caused by the curvature of space-time is $\frac{3}{2}$ the Newtonian gravitational acceleration actually experienced. However this is compensated by an opposite acceleration of $\frac{1}{2}$ Newtonian gravity due to the scalar field.

The composite curvature and scalar field accelerations of a freely falling particle measured in the rest frame of the Centre of Mass (CoM) frame of reference is

$$\frac{d^2r}{dt^2} = -\left\{1 - \frac{G_N M}{r} + ...\right\} \frac{G_N M}{r^2} \ . \tag{17}$$

and the forces acting on a freely falling particle as measured in that rest frame are

$$m_0 \frac{d^2r}{dt^2} = -m(r) \frac{G_N M}{r^2} \ , \tag{18}$$

m_0 can be thought of as "inertial-mass", which measures inertia and $m(r)$ as "gravitational mass", which interacts with the gravitational field with $\underset{r \to \infty}{Lim} \ m(r) = m_0$.

2 Experimental Consequences of the Theory

2.1 The Gravitational Red Shift of Light

In SCC the principle of the local conservation of energy was applied to the gravitational red shift of light. The analysis depended on the assumption that if no work is done on, or by, a projectile while in free fall then its energy E , P^0 , is conserved when measured in a specific frame of reference, that of the CoM of the system.

When a photon is emitted by one atom at altitude x_2 and absorbed by another at an altitude x_1 , the standard time dilation relationship is

$$\frac{\nu(x_2)}{\nu(x_1)} = \left[\frac{-g_{00}(x_2)}{-g_{00}(x_1)}\right]^{\frac{1}{2}} \quad . \tag{19}$$

If $x_2 = r$ and $x_1 = \infty$, where $g_{00}(x_1) = -1$, and writing $\underset{r\to\infty}{Lim}\ \nu(r)$ as ν_0, the standard (GR) gravitational red shift relationship is derived

$$\nu(r) = \nu_0 \left[-g_{00}(r)\right]^{\frac{1}{2}} \quad , \tag{20}$$

where the observer is at infinite altitude observing a photon emitted at altitude r. The next step was to consider the rest mass, $m(r)$, of a projectile launched up to an altitude r while locally conserving energy, the rest mass was evaluated in the co-moving CoM frame as

$$m_c(r) = m_0 \exp\left[\Phi_N(r)\right]\left[-g_{00}(r)\right]^{\frac{1}{2}} \quad , \tag{21}$$

where the observer is at infinite altitude 'looking down' to a similar particle at an altitude r. From this expression it was obvious that with the assumption of the conservation of energy, P^0 , in the CoM frame, gravitational time dilation, the factor $\left[-g_{00}(r)\right]^{\frac{1}{2}}$, applies to massive particles as well as to photons.

As physical experiments measuring the frequency of a photon compare its energy with the mass of the atom it interacts with, it is necessary to compare the masses (defined by Equation 21) of two atoms at altitude, r and ∞, with the energy (given by Equation 20) of a "reference" photon transmitted between them. This yielded the physical rest mass $m_p(r)$ as a function of altitude

$$\frac{m_p(r)}{\nu(r)} = \frac{m_0}{\nu_0} \exp\left[\Phi_N(r)\right] \quad . \tag{22}$$

Equation 22 is a result relating observable quantities, but how is it to be interpreted? In other words how are mass and frequency to be measured in any particular frame? In the GR EF (and BD JF) the physical rest mass of the atom is defined to be constant, hence prescribing $(\widetilde{x}^{\mu})$, with $m_p(\widetilde{r}) = m_0$. In this case Equation 22 becomes

$$\nu(\widetilde{r}) = \nu_0 \left(1 - \widetilde{\Phi}_N(\widetilde{r}) + ...\right) \quad . \tag{23}$$

However in the SCC JF(E) rest mass is given by the expression Equation 6, consequently a comparison of Equation 22 with the equation for rest mass in this frame yields

$$\nu\left(r\right)=\nu_0\ . \tag{24}$$

In the JF(E) the energy of a photons is conserved, even when transversing curved space-time. Gravitational red shift is interpreted as a gain of potential energy, and hence mass, of the apparatus, rather than a loss of (potential) energy of the photon.

Using either frame the gravitational red shift prediction in SCC is in agreement with GR and all observations to date .

2.2 The Observational Tests of SCC

The three original "classical" tests of GR suggested by Einstein; the deflection of light by the sun, the gravitational red shift of light and the precession of the perihelia of the orbit of Mercury, together with the time delay of radar echoes passing the sun, the precession of a gyroscope in earth orbit and the "test-bed" of GR, the binary pulsar PSR 1913 + 16 will now be examined in the SCC JF. In order to demonstrate the conformal equivalence of SCC JF with GR the parameter λ is initially left undetermined.

Now with a general λ the relationship between G_m and G_N was found to be

$$G_m=\frac{(2+\lambda)}{2}G_N\ , \tag{25}$$

and the Robertson parameter γ_r is given by

$$\gamma_r=\frac{(2-\lambda)}{(2+\lambda)} \tag{26}$$

In several classical tests, using the Robertson parameters, a factor Γ appears where:

$$\Gamma=\left(\frac{1+\gamma_r}{2}\right)G_m \tag{27}$$

and substituting for γ_r and G_m it is found that whatever the value of λ

$$\Gamma=G_N\ . \tag{28}$$

2.2.1 The Deflection of Light.

The Robertson parameter expression for the deflection of light by a massive body is

$$\theta = \frac{4G_m M}{R}\left(\frac{1+\gamma_r}{2}\right) = \frac{4G_N M}{R} \ , \tag{29}$$

so for the sun $\theta = 1.75$" in exact agreement with GR and observation.

The deflection, Equation 29 may be divided into two components

$$\theta = \frac{4G_m M}{R}\left(\frac{1}{2}\right) + \frac{4G_m M}{R}\left(\frac{\gamma_r}{2}\right) \ ,$$

the deflection consists of a 'gravitational attraction' of the photon, the effect of the equivalence principle, and an extra deflection caused by curvature. In canonical GR, where $G_m = G_N$ and $\gamma = 1$, the first component is equal to the second and both equal $\frac{2G_N M}{R}$. On the other hand in SCC, $G_m = \frac{3}{2}G_N$, and so the first component is equal to $\frac{3G_N M}{R}$, however as curvature is reduced by a factor $\gamma = \frac{1}{3}$, the second component is only $\frac{G_N M}{R}$, thus resulting in a total deflection of $\frac{4G_N M}{R}$, equal to that of GR.

2.2.2 Radar Echo Delay

The delay in the timing of radar echoes passing the sun and reflected off (say) Mercury at superior conjunction provides a further test for the γ Robertson parameter. The expression for the delay is given by Misner et al. (Misner, Thorne & Wheeler, 1973) as

$$\frac{d\triangle\tau}{d\tau} - (\text{Constant Newtonian part}) = -4\left(1+\gamma_r^{GR}\right)\frac{GM}{b}\frac{db}{d\tau} \tag{30}$$

(where b is the distance of the ray from the earth-sun axis), and experiments have shown $\gamma_r^{GR} = 1$ to a high degree of accuracy. In SCC

$$\frac{d\triangle\tau}{d\tau} - (\text{Constant Newtonian part}) = -8\frac{(1+\gamma_r)}{2}\frac{G_m M}{b}\frac{db}{d\tau} = -8\frac{\Gamma M}{b}\frac{db}{d\tau} \tag{31}$$

therefore, as $\Gamma = G_N$, SCC again predicts the same result as GR.

2.2.3 The Precession of the Perihelia

The precession of perihelia of an orbiting body, primarily the planet Mercury, does not depend on the parameter Γ. It is given in terms of the Robertson parameters as

$$\triangle\theta = \left(\frac{6\pi G_m M}{L}\right)\left(\frac{2-\beta_r+2\gamma_r}{3}\right) \qquad \text{radians/rev.} \tag{32}$$

where L is the semilatus rectum. In SCC, as in BD $\beta_r = 1$ and $\gamma_r = \frac{(2-\lambda)}{(2+\lambda)}$ this yields

$$\triangle\theta = \left(1-\frac{\lambda}{6}\right)\left(\frac{6\pi G_N M}{L}\right) \qquad \text{radians/rev.} \tag{33}$$

However we also have to allow for the effect of the action of the scalar field which modifies Newtonian gravitation according to Equation 17, using units with $c \neq 1$ this becomes,

$$\frac{d^2r}{dt^2} = -\left[1-\lambda\frac{G_N M}{rc^2}\right]\frac{G_N M}{r^2}\ . \tag{34}$$

This can be considered as the acceleration produced by a Newtonian potential with a dipole-like perturbing potential

$$\Phi = -\frac{G_N M}{r} + \frac{1}{2}\lambda\left(\frac{G_N M}{rc}\right)^2 \tag{35}$$

This non-Newtonian perturbation produces an extra precession of a factor

$$\frac{\lambda}{6}$$

of the full GR perihelion advance. Combining this extra perihelion advance with that caused by the curvature of space-time in Equation 33 results in a SCC prediction of a PNA perihelion advance equal to

$$\triangle\theta = \frac{6\pi G_N M}{L} \qquad \text{radians/rev.} \tag{36}$$

So there is in exact agreement with the canonical GR value. Note this additional precession is that of the 'semi-relativistic' adaptation of the mass that includes potential energy in Newtonian orbital dynamics.

2.2.4 The Binary Pulsar PSR 1913 + 16

A neutron star, composed of relativistic matter with an equation of state of

$$p_n = \frac{1}{3}\rho_n$$

will be de-coupled from the scalar field. Without further analysis it seems likely that any predictions of Binary pulsar loss of orbital energy due to gravitational radiation will be the same as GR. However in the formation of a collapsed star the gravitational field would appear to increase by a factor of 1.5 as the gravitating mass became degenerate and de-coupled from the scalar field.

2.2.5 The Precession of a Gyroscope

The effect of the curvature of space-time on the precession of a gyroscope in earth orbit is similarly compensated for by the scalar field. The component $\overset{3}{g}_{i0}$ was calculated to be ([Barber,2002a), (Weinberg,1972):

$$\nabla^2 \overset{3}{g}_{i0} = 16\pi G_m \left(\frac{2\varpi+3}{2\varpi+4}\right) \overset{1}{T}{}^{i0} + \left(\frac{2}{\varpi+2}\right) \frac{d^2\Phi_m}{dx^i dt} \ ,$$

and therefore for a static system

$$\overset{3}{g}_{i0} = -4G_m \left(\frac{2}{2+\lambda}\right) \int \frac{\overset{1}{T}{}^{i0}(x',t)}{|x-x'|} d^3x \ . \tag{37}$$

Now

$$G_m \left(\frac{2}{2+\lambda}\right) = \Gamma \tag{38}$$

As $\Gamma = G_N$, the effects of the rotation of the earth, or any central spherical mass, on the precession of spins and perihelia are the same in this theory as in canonical GR. (GR may be obtained by letting $\lambda \to 0$ in Equation 37.) Hence in the Gravity Probe B Lense-Thirring experiment SCC predicts the identical result as GR.

3 The Definitive Experiments

3.1 Do Photons fall at the same rate as Particles?

The identical predictions in the One-Body Problem in GR and SCC raise the question "Is SCC just GR rewritten in some obscure coordinate system, the JF(E) rather than the EF?" That this is not so and SCC is indeed a separate theory from GR may be seen when the behaviour of light is compared with that of matter in free fall. Although the prediction of the deflection of light by massive bodies is equal in both theories, in SCC a photon in free fall descends at $\frac{3}{2}$ the acceleration of matter. i.e. in free fall a beam of light travelling a distance l is deflected downwards, relative to physical apparatus, by an amount

$$\delta = \frac{1}{4} g \left(\frac{l}{c} \right)^2 \ . \tag{39}$$

As a possible experiment I suggest launching into earth orbit an annulus, two meters in diameter, supporting 1,000 carefully aligned small mirrors. A laser beam is then split, one half reflected, say 1,000 times, to be returned and recombined with the other half beam, reflected just once, to form an interferometer at source. If the experiment is in earth orbit and the annulus orientated on a fixed star, initially orthogonal to the orbital plane then the gravitational or acceleration stresses on the frame, would vanish whereas they would predominate on earth. In orbit SCC predicts a 2 Angstrom interference pattern shift with a periodicity equal to the orbital period whereas GR predicts a null result.

3.2 Is there a Cut-Off to the Casimir Force?

In the JF gravitational acceleration, Equation 18, can be expressed as

$$\frac{d^2 r}{dt^2} = - \exp\left(\Phi_N\right) \frac{G_N M}{r^2} \ , \tag{40}$$

and hence it followed that

$$\nabla \left[\exp\left(-\Phi_N\right) \right] = - \frac{G_N M}{r^2} \tag{41}$$

so,

$$\Phi_N = - \ln \left(1 + \frac{G_N M}{r} \right) \ . \tag{42}$$

On the other hand in the EF $\widetilde{m}(\widetilde{r}) = m_0$, therefore Equation 18 reduces to the normal Newtonian/GR expression

$$\frac{d^2\widetilde{r}}{d\widetilde{t}^2} = -\frac{G_N\widetilde{M}}{\widetilde{r}^2} \ . \tag{43}$$

This is derived, of course, from the usual EF Newtonian potential

$$\widetilde{\Phi}_N = -\frac{G_N\widetilde{M}}{\widetilde{r}} \ . \tag{44}$$

The difference in the Newtonian potentials for the two frames is the consequence of the SCC EF having a classical Lagrangian and the JF(E) having a non-classical Lagrangian *in vacuo*. This difference between the classical EF and non-classical JF(E) manifests itself in the vacuum solution to the field equations. In the JF(E) the Newtonian potential solution, obtained from the principle of the conservation of energy, requires an additional traceless potential of

$$\nabla\Phi_N = -\left[\frac{G_N M}{r}\right]^2 \tag{45}$$

to that of the vacuum solution derived from the Principle of Mutual Interaction. This is the Newtonian potential of a small "quantum ether" vacuum density ρ_{qv} where

$$\rho_{qv} = -\frac{1}{2\pi}\frac{G_N M}{r}\frac{M}{r^3} \ . \tag{46}$$

Furthermore, introducing ρ_{av} as the average matter density inside the sphere, radius r, centered on the gravitating mass M, this can be written as

$$\rho_{qv} = -\frac{2}{3}\frac{G_N M}{r}\rho_{av} \ . \tag{47}$$

The negative sign is consistent with standard analysis of the Casimir effect in which the "quantum ether" between the Casimir conductors has a negative energy density. So in a laboratory near the earth

$$\rho_{qv\oplus} \simeq -2.4 \times 10^{-9} \ \text{gm.cm}^{-3} \ . \tag{48}$$

This density is proportional to r^{-4} and limits the maximum Casimir force that might be detected. This limit may be detectable at a sufficient distance from gravitational masses. Thus the theory implies that in flat space-time, in

the absence of gravitational fields, the Casimir force would not be detectable at all! The theory does suggest that an experiment launched away from the sun, which compared the Casimir force against separation, would detect the force rounding off as the limit to the Casimir effect was reached. This limit may be detected at around 5 A.U. with current experimental sensitivity.

3.3 Geodetic Precession

The Gravity Probe B experiment, successfully completed in September 2005 and now in a prolonged data analysis phase, has compared the spin directions of an array of four redundant gyroscopes. It is testing the Lense-Thirring or frame-dragging effect, in which the SCC prediction is equal to that of GR as above in Equation 37. This is a value of 0.042 arc/yr about a direction parallel to the direction of the Earth's rotation axis. (Keiser,G.M., et al, 2002). The interesting aspect from the SCC point of view is that the experiment is also measuring the geodetic effect. This effect is described by the expression (Will, 2002)

$$\frac{1}{2}\left(2\gamma+1\right)\frac{GM_{\oplus}}{R^{3}}\mathbf{v}_{s}\times\mathbf{X} \tag{49}$$

which in GR, where $\gamma = 1$ and $G = G_N$, predicts a precession for the Gravity B Probe gyroscope of 6.6 arc sec/yr about a direction perpendicular to the plane of the orbit, this is given by,

$$\Omega = \mathbf{v}\times[-\frac{1}{2}\mathbf{a}+(\gamma+\frac{1}{2})\boldsymbol{\nabla}U], \tag{50}$$

where $\mathbf{a}$ is the acceleration from the geodesic and $U = -\Phi$ is the 'Newtonian' potential of the metric being considered.

In SCC $\gamma = \frac{1}{3}$ and $G = G_m = \frac{3}{2}G_N$, i.e. $\boldsymbol{\nabla}U_m = \frac{3}{2}\boldsymbol{\nabla}U_N$, so the theory predicts a geodetic precession of 5/6 of the GR geodetic precession or just 5.5 arc sec/yr. However, a further correction has to be made to the SCC prediction. The satellite in drag-free mode in orbit is not travelling along a geodesic of the SCC metric but perturbed from it by the scalar field force. The inertial acceleration produced by this force is given by, $\mathbf{a} = \frac{1}{3}\boldsymbol{\nabla}U$. The Thomas precession correction is thus $\mathbf{v}\times 1/6\boldsymbol{\nabla}U$, i.e. -1/6 the GR geodetic precession. Therefore the SCC prediction of the total precession about a direction perpendicular to the plane of the orbit is 2/3 the GR value. That is SCC predicts a N-S precession of 4.4096 arcsec/yr.

4 Conclusions

4.1 A Summary

Two key aspects of the theory are Firstly it is not a classically metric theory, it is a 'semi-metric' theory in which:

- photons follow geodesics; but particles do not, the Principle of Equivalence is replaced by the Principle of Mutual Interaction.

Secondly, there is a conformal equivalence *in vacuo* between the Jordan frame and GR in its Einstein frame,

- the JF(E) describes curvature and conserves mass-energy

and in the EF, which is canonical General Relativity *in vacuo*, four-energy-momentum is conserved.

Consequently test bodies falling freely *in vacuo* experience a scalar field force that exactly compensates for the effect of the scalar field on curvature. Particles follow GR geodesics *in vacuo. In vacuo* there is a degeneracy between GR and SCC that is only resolved in the definitive experiments described above. In the cosmological solution where there is a homogeneous density the solution does differ from the standard GR solution and yields a concordant cosmological model that does not require the unverified physics of inflation, exotic Dark Matter or Dark Energy.

As calculated in the earlier paper (Barber, 2002a), the gravitational constant G_m, that determines the coupling of matter to curvature, is greater by a factor $\frac{3}{2}$ from that measured as Newtonian G_N in Cavendish type experiments. As shown above this increase compensates for the reduced value of $\gamma = \frac{1}{3}$. Thus, using Newtonian G_N, interpretations of the data in the deflection of light, frame dragging, and radar echo delay experiments would determine a $\gamma = 1$.

The geodetic measurement, which considers the Earth - Moon system as a gyroscope, would also appear to be similarly compensated. This is because, as it is an extended, gravitationally bound system *in vacuo*, the problem can be considered in the Einstein frame of the theory, which is canonical GR. The Earth and Moon follow their GR geodesic trajectories through space-time.

As a result of this conformal equivalence between the two theories it has not been possible to distinguish SCC from GR in all previous solar system experiments, there is a degeneracy in these tests between the two theories. There are the two possible further experiments as suggested above, which would distinguish between them. But also, there is the third experiment

being evaluated at present, the Gravity Probe B satellite, which is able to differentiate between the two theories and resolve the degeneracy.

As the gyroscopes in the Gravity Probe B experiment are solid and their interiors not '*in vacuo*' the experiment cannot be conformally transformed into a canonical GR Einstein frame. It is a 'point' measurement of curvature and as such it is the first non-null experiment to distinguish between GR and SCC. As the results of this experiment are about to be published in 2006/7, it will imminently provide the first occasion to test SCC against GR and therefore this experiment presents an important opportunity to falsify the theory.

4.2 The prediction

In the Gravity Probe B satellite experiment SCC and GR predict gyroscope precessions, about a direction perpendicular to the plane of the orbit, of 4.4096 arcsec/yr and 6.6144 arc sec/yr respectively.

4.3 Acknowledgments

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